

A FUNCTION-BASED APPROACH TO COCKPIT PROCEDURE AIDS

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ABSTRACT

The objective of this research is to develop and test a cockpit procedural aid that can compose and present procedures that are appropriate for the given flight situation; described by the current phase of flight, the status of the aircraft engineering systems, and the environmental conditions. Prescribed procedures already exist for normal as well as for a number of non-normal and emergency situations, and can be presented to the crew using an interactive cockpit display. However, no procedures are prescribed or recommended for a host of plausible flight situations involving multiple malfunctions compounded by adverse environmental conditions. Under these circumstances, the cockpit procedural aid must review the prescribed procedures for the individual malfunction (when available), evaluate the alternatives or options, and present one or more composite procedures (prioritized or unprioritized) in response to the given situation.

A top-down function-based conceptual approach towards composing and presenting cockpit procedures is being investigated. This approach is based upon the thought process that an operating crew must go through while attempting to meet the flight objectives given the current flight situation. In order to accomplish the flight objectives, certain critical functions must be maintained during each phase of the flight, using the appropriate procedures or success paths. The viability of these procedures depends upon the availability of required resources. If resources available are not sufficient to meet the requirements, alternative procedures (success paths) using the available resources must be constructed to maintain the critical functions and the corresponding objectives. If no success path exists that can satisfy the critical functions/objectives, then the next level of critical functions/objectives must be selected and the process repeated.

Thus, at any given time during a flight, a function-based cockpit procedure performs the following operations:

- * Situation Assessment
 - Phase of flight
 - Aircraft engineering systems status (malfunction)
 - Environmental conditions
- * Procedure Selection
 - Present prescribed procedures (when available)
 - Perform critical functions/success path analysis
 - Present alternative procedures/consequences

This function-based approach to cockpit procedural aids is demonstrated through application to flight scenarios where multiple malfunctions occur during the course of the flight.

Problem Description

OVERALL OBJECTIVE OF A FLIGHT:

- **MOVE PASSENGERS FROM ORIGIN TO DESTINATION WHILE CONSIDERING THE FOLLOWING FACTORS**
 - SAFETY
 - SCHEDULE
 - EFFICIENCY
 - COMFORT
- **CREW MUST CONTINUALLY PERFORM THE FOLLOWING FUNCTIONS:**
 - SITUATION MONITORING
 - SITUATION ASSESSMENT
 - EVALUATE ALTERNATIVES
 - SELECT PROCEDURES
- **COCKPIT PROCEDURAL AID CAN ASSIST THE CREW IN EVALUATING ALTERNATIVES AND SELECTING PROCEDURES**

Project Objectives

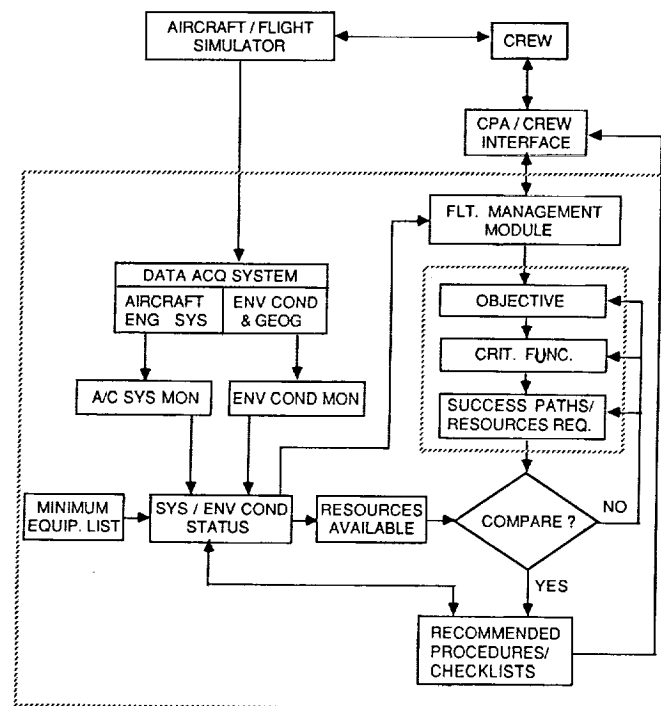
TO DEVELOP A COCKPIT PROCEDURAL AID (CPA) TO

- **PRESENT THE PRESCRIBED PROCEDURES UNDER**
 - NORMAL CONDITIONS
 - NON-NORMAL CONDITIONS
 - EMERGENCY CONDITIONS
- **DEVELOP/PROVIDE RECOMMENDATIONS FOR MULTIPLE MALFUNCTIONS**
 - **PRESENT PRESCRIBED PROCEDURES CORRESPONDING TO EACH MALFUNCTION AND THEIR CONSEQUENCES**
 - **PRESENT COMPOSITE PROCEDURES BY AGGREGATING THE INDIVIDUAL PRESCRIBED PROCEDURES**
 - **WHERE NO PRESCRIBED PROCEDURES ARE AVAILABLE, RECOMMEND ALTERNATIVES AND PRESENT CONSEQUENCES**
- **PRESENT CONSEQUENCES OF CREW INITIATED DECISIONS AND ACTIONS**

Characteristics of Flight

- EVERY FLIGHT CAN BE HIERARCHICALLY DECOMPOSED INTO A NUMBER OF PHASES, SEGMENTS, AND SUB-SEGMENTS
- OVERALL FLIGHT AND ITS INDIVIDUAL PHASES, SEGMENTS, AND SUB-SEGMENTS HAVE
 - OBJECTIVES
 - CRITICAL FUNCTIONS
 - SUCCESS PATHS
- OBJECTIVE IS TO FOLLOW A PRESCRIBED FLIGHT PROFILE
- A CRITICAL FUNCTION IS A FUNCTION THAT MUST BE MAINTAINED TO FOLLOW A FLIGHT PROFILE
- CRITICAL FUNCTION ACCOMPLISHED BY ONE OF SEVERAL SUCCESS PATHS
- A SUCCESS PATH IS A SET OF RECOMMENDED ACTIONS (PROCEDURES) FOR MAINTAINING THE CRITICAL FUNCTION
- EACH SUCCESS PATH (PROCEDURES) HAS A DEFINITE SET OF RESOURCE REQUIREMENTS
- PATH CHOSEN BY MATCHING REQUIREMENTS WITH AVAILABLE RESOURCES
 - ENGINEERING SYSTEMS
 - ENVIRONMENT

COCKPIT PROCEDURAL AID - CPA

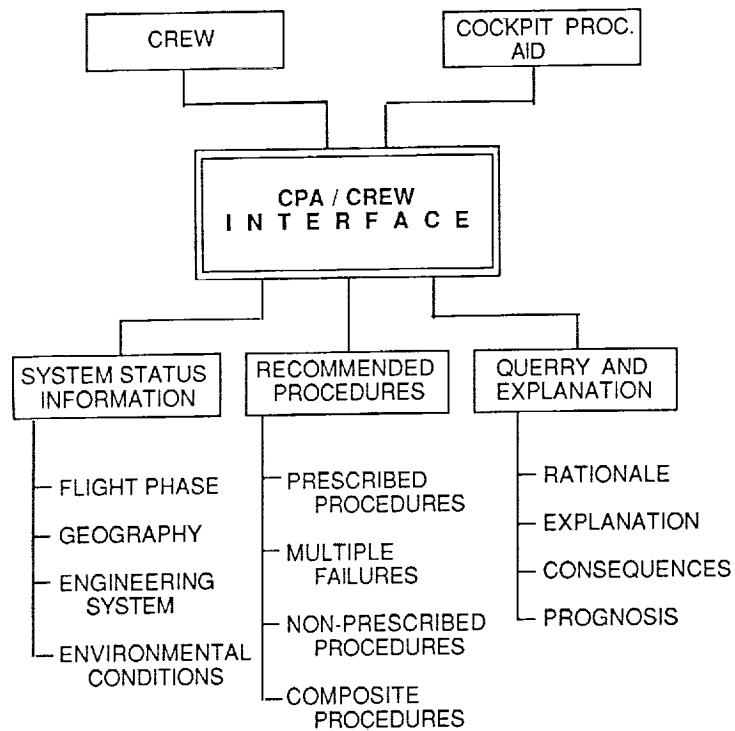


Flight Management Module

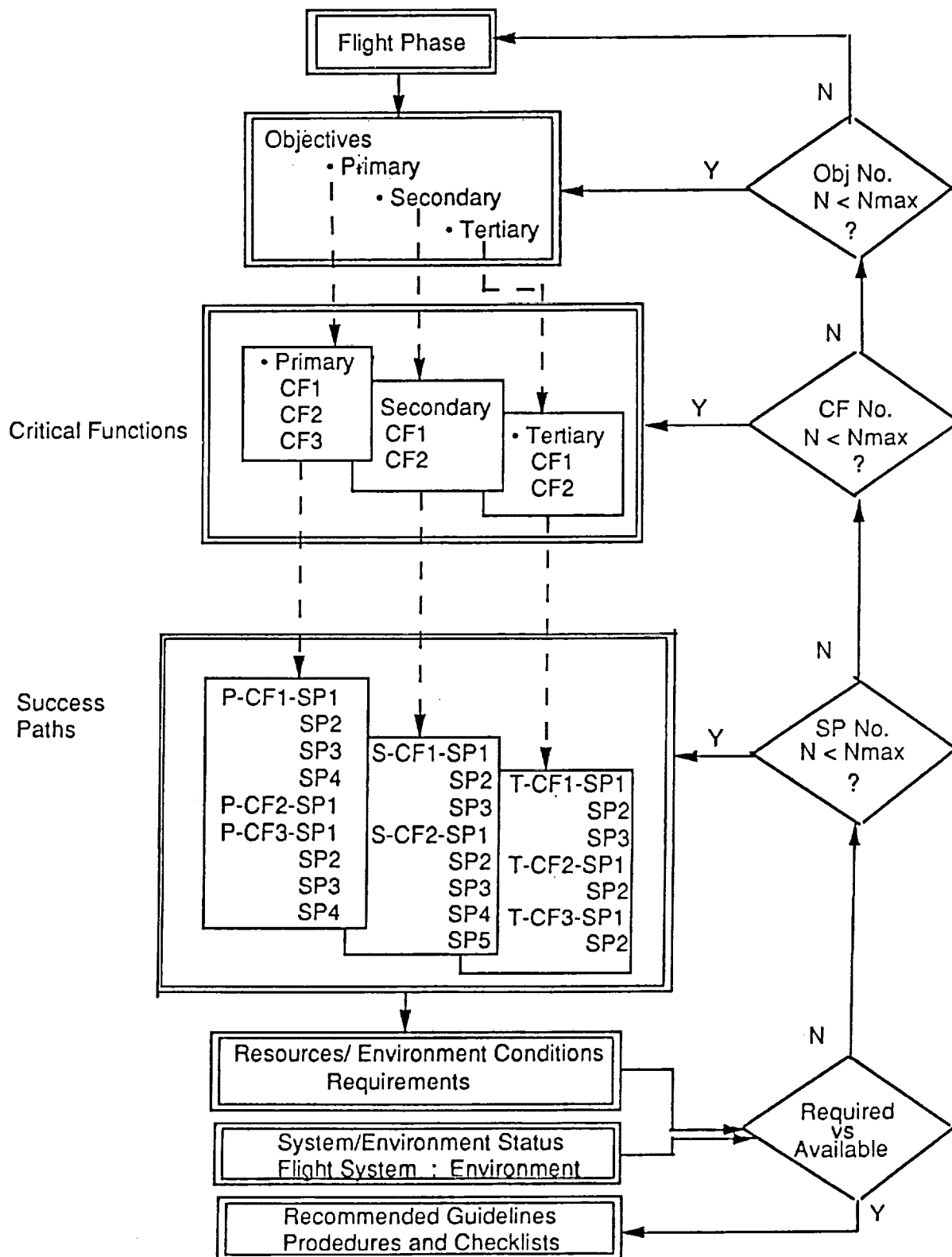
MONITORS THE GLOBAL FLIGHT OBJECTIVES

PERFORMS THE FOLLOWING FUNCTIONS:

- MONITOR THE SITUATION
 - PHASE OF FLIGHT
 - GEOGRAPHICAL LOCATION
 - FUEL STATUS
- MONITOR VEHICLE CONTROL AND STABILITY
- INTERFACE WITH FLIGHT MANAGEMENT COMPUTATIONS
 - TIME ELAPSED / TIME TO DESTINATION
 - DISTANCE FROM DESTINATION
 - FUEL REMAINING / BUDGET CALCULATIONS



Critical Function/Success Path Logic



Examples

- OVERALL FLIGHT
 - OBJECTIVES: FLY TO DESTINATION USING A SAFE AND FUEL EFFICIENT FLIGHT PROFILE
 - CRITICAL FUNCTIONS:
 - VEHICLE STABILITY / CONTROLLABILITY
 - FUEL REMAINING
 - SUCCESS PATHS:
 - FUEL MANAGEMENT METHODS
 - ALTERNATE VEHICLE CONFIGURATIONS
 - RESOURCES REQUIRED:
 - FUEL SYSTEM
 - AIRCRAFT ENGINEERING SYSTEMS
 - ENVIRONMENTAL CONDITIONS
- LANDING PHASE
 - OBJECTIVES: LAND WITH PRESCRIBED SPEED
 - CRITICAL FUNCTIONS: THRUST AND LIFT
 - SUCCESS PATH: HIGH LIFT DEVICES, CONTROL SURFACES, THROTTLE, WEIGHT (FUEL)
 - RESOURCES REQUIRED: AIRCRAFT ENGINEERING SYSTEM, ENVIRONMENTAL CONDITIONS

Candidate Scenario #1

FLIGHT: SACRAMENTO TO LOS ANGELES

FLIGHT PLAN:

SMF.FOGGO5.FRA.J7.DERBB.FIM4.LAX FL 330

MALFUNCTIONS:

- DURING CRUISE GEN #1 TRIPS
- AT TOD ENG #3 OP DEC. TO 36 PSI, OT INC

QUICK SITUATION ASSESSMENT BY CREW AND CPA

- GEN-1 CIRCUIT LIGHT ON
- PRESCRIBED IRREGULAR PROCEDURE
 - CHECK BUS TIE CIRCUIT OPEN LIGHTS (NO)
 - FIELD LIGHTS ON (NO)
 - VOLT AND FREQ NORMAL (YES)
 - CHECK GEN CIRCUIT OPEN LIGHTS OFF (NO)
 - PRESCRIBED ACTION ITEMS:FOLLOW 2-GEN OPER IRR PROC TO DROP ELEC LOAD BELOW 54 KW

Candidate Scenario #1 (cont)

- ENG-3 LOW OIL PRESS LIGHT ON
- PRESCRIBED IRREGULAR PROCEDURE
 - OIL PRESS BELOW 35 PSI (NO)
 - REDUCE THRUST
 - LOW OIL PRESS LIGHT ON (YES)
 - ACCOMPLISH IRR PROC FOR ENG-3 SHUTDOWN,
OR REDUCE THRUST TO MIN REQUIRED

OPTION 1: SHUTDOWN ENG-3

- CONSEQUENCE: 2 ENG AND 1 GEN OPERATING
 - LOAD < 36 KW, POSSIBLE CABIN PRESS PROBLEMS
AND HIGH RISK UNDER NIGHT CONDITIONS,
POSSIBLE FUEL UNBALANCE PROBLEM

OPTION 2: REDUCED MIN THRUST ENG-3

- CONSEQUENCE: 2 ENG AND 2 GEN OPERATING
 - LOAD < 54 KW, MAX 20 MIN FLYING TIME

Candidate Scenario #2

FLIGHT: LOS ANGELES TO SACRAMENTO

FLIGHT PLAN:

LAX.GMN6.EHF.365.CZQ.WRAPS4.SMF FL 310

MALFUNCTIONS:

- NEAR TOD FUEL LEAK IN TANK #3 (APPROX. 500 LB/MIN),
STOPS BELOW 1800 LBS OF FUEL
- #7 LEADING EDGE SLAT DOES NOT EXTEND

QUICK SITUATION ASSESSMENT BY CREW AND CPA

- 1000 LB FUEL TANKS 1 AND 3 DIFF (POSSIBLE
EARLIER DETECTION BY CPA)
- PRESCRIBED IRREGULAR PROCEDURE
 - NONE
 - VIOLATION OF FUEL UNBALANCE
SPECIFICATIONS/LIMITATIONS

FLIGHT MANAGEMENT OBJECTIVES:

- VEHICLE STABILITY / CONTROLLABILITY
- LAND AT THE INTENDED DESTINATION
- POSSIBLE CONFLICT DEPENDING ON PRIORITY

Candidate Scenario #2 (cont)

OPTION 1: PRIORITY ON VEHICLE STABILITY ONLY

- BALANCE TANK FUEL BY DUMPING FROM TANK #1
- MANAGE FUEL FLOW CONFIGURATION TO PREVENT ENG-3 FLAMEOUT
- EVALUATE AND RECOMMEND LANDING SITE

OPTION 2: REACH DESTINATION WITH ACCEPTABLE VEHICLE STABILITY

- PRESENT ALTERNATIVE FUEL FLOW CONFIGURATIONS TO OPTIMIZE FUEL CONSUMPTION
- EVALUATE CONSEQUENCES OF EACH CONFIGURATION OPTION
- RECOMMEND LANDING SITE OPTIONS

Implementation

- IMPLEMENTED ON PERSONAL COMPUTER AND VAX WORKSTATION
- CUSTOM APPLICATION BUILT FROM GENERIC TOOLS
- OBJECT-ORIENTED REPRESENTATION:
 - AIRCRAFT ENGINEERING SYSTEMS
 - ENVIRONMENTAL CONDITIONS
 - FLIGHT MANAGEMENT MODULE
 - CRITICAL FUNCTION
 - SUCCESS PATHS (PROCEDURES/CHECKLISTS)
- FRAME-BASED INFERENCING (FLIGHT MANAGEMENT/ CRITICAL FUNCTION/SUCCESS PATH EVALUATION)
 - LOGIC FLOW INFERENCE ENGINE
 - FRAMES REPRESENTED IN TERMS OF OBJECTS
 - REASONING USING FORWARD AND/OR BACKWARD CHAINED RULES
- INTERFACE TO AIRCRAFT OR FLIGHT SIMULATOR
- MAN-MACHINE INTERFACE:
 - EASE+ - A GRAPHICAL DATA BASE MANAGEMENT ENVIRONMENT
 - PROVIDES ENVIRONMENT FOR INTERACTION BETWEEN USER, DATABASE, FLIGHT MANAGEMENT MODULE AND SIMULATOR
 - GRAPHICAL AND SYNOPSIS PRESENTATION OF ALL RELEVANT INFORMATION

Remaining Work

- **COMPLETE PROTOTYPE IMPLEMENTATION OF COCKPIT PROCEDURAL AIDS METHODOLOGY**
- **DEVELOP AND TEST COCKPIT PROCEDURAL AIDS METHODOLOGY USING 2 OR 3 FLIGHT SCENARIOS AS EXAMPLES**

